Passive Solar

Introduction

A home with passive solar features uses the sun's energy for space heating. This publication explains how passive solar heating works and gives basic rules that are sensitive to Alberta's climate and latitude. You will not be able to design passive solar features after you have read this -- there are shelves of information you need for that -- but you will be able to tell a designer or architect more clearly how you want to use passive solar heating and be able to participate more in the design process.

This publication is in two parts. The first defines what we mean by passive solar heating and is followed by principles for passive solar design. The second section applies these guidelines to two examples.

The starting point for passive solar design is an energy efficient house. The amount of energy the house needs must be reduced before the sun can make a significant contribution to space heating. Improving the energy efficiency also makes economic sense: it is the least expensive first step to reduce utility bills. This booklet assumes that if you are considering passive solar features, you are planning to build or renovate to energy efficient standards. In a new home, this means a well-sealed building with balanced central ventilation and insulation levels of RSI 5 to 5.25 (R 28 to 30) in the walls, RSI 7 to 8.75 (R 40 to 50) in the ceiling, and RSI 3.5 (R 20) in the basement. The RSI value (R value) refers to the resistance to heat flow - the higher the better. In a renovated home, it means coming as close to these guidelines as possible.

A passive solar home should have lower utility bills and more daylight than most others. Many are heated almost exclusively with the sun. Taking advantage of the sun, however, is just one priority you should have when you design or renovate. Most of all, your home should be a place where you like to live. No amount of passive solar design will make you feel better about a poor view, an interior finish you do not like, or a floor plan that lacks privacy. Design your home for comfortable living first -- to suit your family's tastes, use of space, and work and play habits -- then adapt solar features to the plan.

What is Passive Solar Heating?

Solar heating, whether active or passive, has three key elements: a means to capture heat from the sun, a means to distribute the heat, and a way to store it, if necessary. In passive solar heating, these elements are integrated into the architecture and can function without mechanical assistance. Fans and controls enhance the performance of a passively heated space, but are not essential.

By contrast, active solar heating uses special solar collectors, pumps, fans and a means of storing the sun's energy separately from the space requiring heat. Without mechanical assistance, no heat would be delivered. Compared to passive solar heating, active solar is not as good an option for space heating in Alberta because it is complicated and expensive.

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As Figure 1 illustrates, a passive solar space gains heat from the sun either directly or indirectly. A direct gain system uses features of the space itself -- walls and floors, for example -- to collect and distribute the sun's energy. An indirect gain system uses a special heat-absorbing object, such as a concrete wall, between the sun and the space requiring heat. Indirect gain is less efficient in our climate than direct gain.

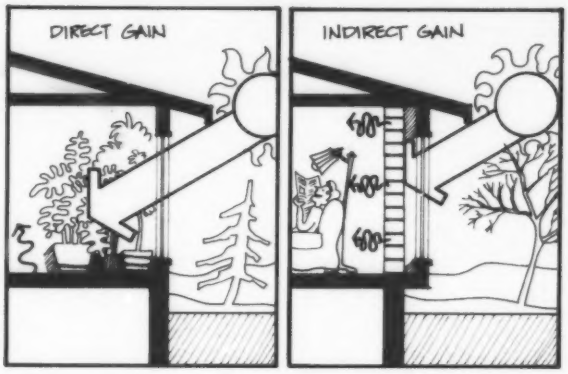

Figure 1 Types of passive solar gain

Attached sunspaces combine the principles of direct and indirect gain. The sunspace itself is a direct gain space but it acts like an indirect gain system when it is used to heat a house. The sun's heat is released from the greenhouse to the house, rather than accumulating in the house directly.

In a direct gain space, windows oriented toward the sun capture the sun's energy. Sunlight enters a window, strikes objects, and is converted into heat. Passive solar heating, however, involves more than adding windows to the solar side of the house. For example, the area of the windows should balance the energy needs and heat-storing capacity. The house should be well-insulated and well-sealed to take best advantage of heat from the sun. Heating and ventilating systems should be designed to help circulate solar-heated air. Passive solar heating requires a well-balanced system of elements.

Principles for Passive Solar Design in Alberta

Well-designed passive solar features take into account all details of site and house plan: windbreaks; heat absorbing characteristics of building materials; solar gain through windows on an hour-by-hour basis; and passageways and obstacles to air movement. The principles outlined here should be considered when designing passive solar features in Alberta, but a detailed design is necessary to ensure a system that works well for your site and your house plan.

Designing passive solar features has three requirements: getting sunlight into the house so it can be used for heat; distributing that heat around the house; and incorporating materials capable of storing heat if necessary. The following principles would be best for passive solar design, all else being equal. Other considerations -- comfort, esthetics, cost -- bend the rules.

Letting the Sun In

Shape, orientation, siting and window design all affect how much sunlight enters.

Shape

In this climate, the best house shape is a compromise between least heat loss and most solar gain. To control heat loss, minimize the exterior surface area of the house; the more you deviate from a square floor plan, the more exterior wall you will have for the same floor area. To boost solar gain, the south-facing wall should be maximum size; for the same floor area, a rectangle on an east-west axis gives a bigger south-facing surface. A moderately elongated shape is the best compromise for prairie climates.

Shape is not a big factor in passive solar performance. The penalty for choosing a more complicated and interesting floor plan, within reason, is small.

Orientation

Whether building a home or adding a sunspace, most of the glass should face south. (Note that the south indicated on a compass, or magnetic south, is west of true south in Alberta. The designer or architect should correct for this error, which varies widely across the province.) At our latitudes, the winter sun is in the southern sky. It rises and sets in the southeast and southwest and stays low on the southern horizon. During

the heating season, windows facing due south consequently get the most light, but up to 90 per cent of this light is available within 30 degrees east or west of due south (Figure 2). The penalty becomes greater the farther from south you vary (Table 1). Houses oriented east of south have the advantage of warming up more quickly in the morning; houses oriented west of south stay warm longer into the evening and tend to overheat from low afternoon sun angles in late spring and early fall.

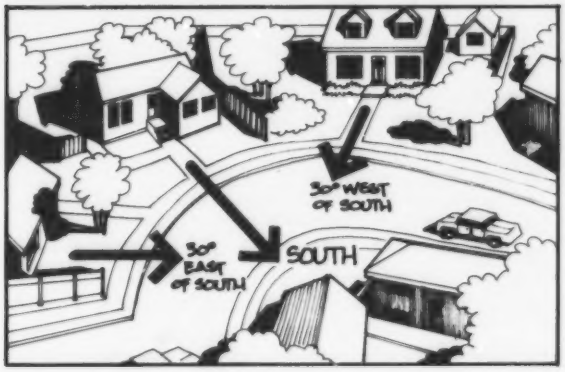

Figure 2 South-facing windows get the most light, but 90 per cent is available within 30 degrees east or west of due south.

Table 1

Amount of Sunlight on windows in various orientations (for 52 degrees latitude, October to April)

Orientation	% south-facing light
S	100
SW	74
W	32
NW	10
N	8
NE	10
E	32
SE	74

Windows facing southeast and southwest get the most sun in summer. The summer sun rises north of east, sets north of west, and makes an arc tipped a little to the south. For long periods, the sun has access to windows facing east and west, and especially southeast and southwest. Skylights will also get a great deal of sun. If you plan skylights or place windows east or west of south, shade them during the summer to prevent overheating and use glazing with a reflective quality.

Siting

Choose a site that will give your home access to the sun. In a rural area this is not usually a problem. In an urban area, however, choose a lot that faces either north or south so that the solar side of the house faces the street or the backyard, not your neighbour's wall. Figure 3 shows good solar lots in a typical subdivision.

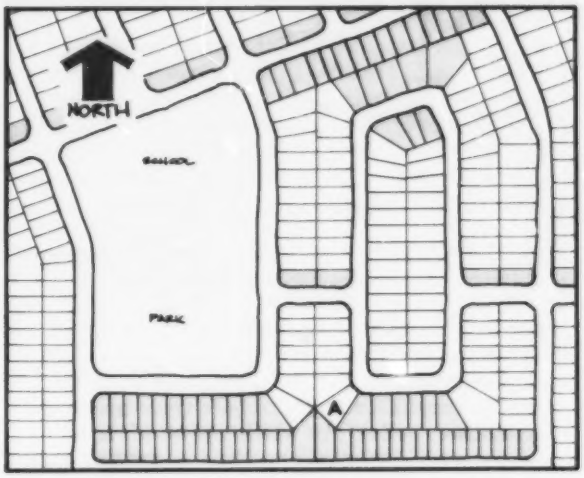

Figure 3 The best solar lots have a north-south axis or have an exposed south side.

Siting a house on an urban lot is complicated by regulations restricting how close to the front, back and sides of the property you can build. Some lots may have other restrictions: how high you can build and where you can put windows. Check these restrictions with the municipal building permits office before you buy a lot.

Make sure trees and buildings do not block the sun from the windows you want to use for solar gain. During the heating season, the sun delivers over 90 per cent of its energy between 9 a.m. and 3 p.m. These are the important times to keep your solar-facing windows free of shadow (Figure 4). Even low hills or nearby windbreaks, forests or buildings can block the winter sun when it is close to the horizon.

On an urban lot, be careful of shading from adjacent, as well as facing, houses. Neighbouring houses that extend past the solar side of your house may block the morning and afternoon sun.

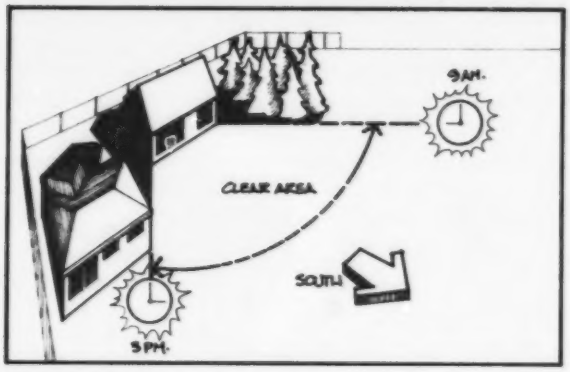

Figure 4 Ninety per cent of the sun's energy is delivered between 9 a.m. and 3 p.m.

Site the house to use trees, hills, and existing buildings as windbreaks on the windward side. It is particularly easy to take advantage of these opportunities on a rural lot where there are fewer regulations.

Window Design

Windows are the critical elements in passive solar heating. Their orientation, number and type of panes, size, shading and slope all affect the amount of heat gained from the sun.

Orientation and glazing for solar-facing windows. Windows both gain and lose heat. They gain heat according to how much sunlight enters. This is determined by orientation and by number and type of glazings. A glazing is a single layer of transparent material such as glass, plastic or film. The greater the number of glazings, the less light penetrates. Windows lose heat according to their area and their insulation value. As area increases, heat loss increases. As insulation value increases, however, heat loss decreases. The insulation value of a window is determined mainly by its number and type of glazings: the more glazings, the higher the insulation value. Single pane windows thus admit the most light but have the lowest insulation value. *Windows* describes the advantages and disadvantages of a variety of glazings.

To contribute heat to your home, windows must gain more heat than they lose. In other words, they must have a **net heat gain**. Figure 5 shows how orientation and type of glazing affect the net heat gain of windows during an Alberta heating season. Values above zero on the chart mean gains are greater than losses and the window is helping to heat the house.

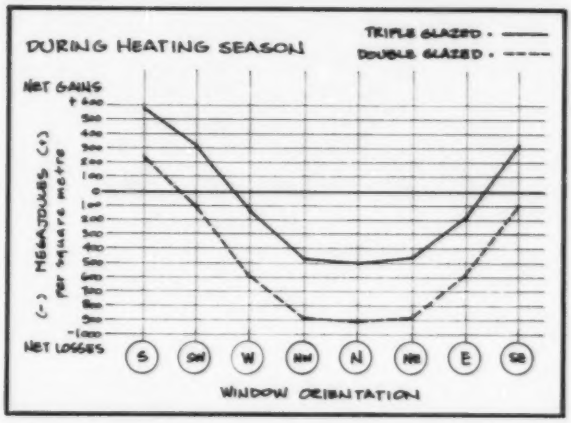

Figure 5 Comparison of net heat gains for different types of glazings

Net heat gains are higher for triple-pane than double-pane windows in our climate. **Over the course of the heating season, south-facing triple-pane windows will contribute more than twice the net heat than double-pane windows in the same orientation.** Triple glazing converts southeast and southwest windows from net heat losers to net heat gainers and dramatically reduces the heat loss of windows facing other directions. Standard low-emissivity windows (double-pane windows that have a special insulative coating) have similar insulation values to triple-pane windows but admit about 10 per cent less light.

The sun is an important source of light as well as a heat source. If most of your windows face one way for solar gains, how does that affect the amount of daylight in the rest of the house? The Alberta Building Code ensures adequate daylight by specifying minimum window-to-floor-area ratios that each room must meet. Windows in the east, north, and west walls will help provide adequate light but will increase heat losses. Choose high RSI (R) value windows for these walls. Clerestory windows and skylights are other ways to increase daylight. As they can face south, they can increase daylight with less heat loss (Figure 6). Clerestories are a better option than skylights because they let in more winter sun, are easier to shade in summer, and are more cost-effective.
South-sloping skylights can cause overheating in summer.

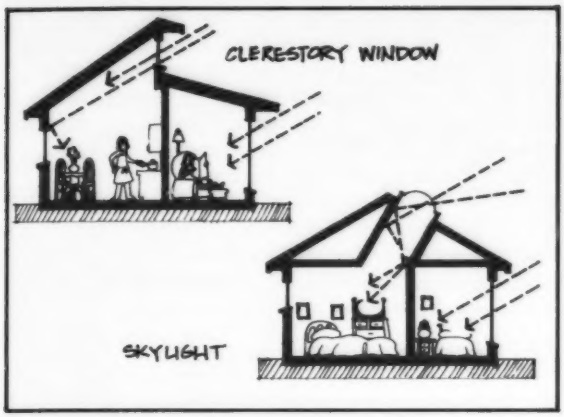

Figure 6 Options to provide daylight

Sizing solar-facing windows. The solar-facing window area is usually expressed as a percentage of floor area, where the floor area includes direct-gain spaces and rooms that open on to them. (Unless a basement has more than one or two small windows, its area is not usually counted.) For every house, there is an optimum area of south-facing glass that will result in the lowest possible heating bill. This optimum area depends on the energy efficiency of the house, its mass, volume and the level of glazing on south-facing windows. Though optimum from an energy cost perspective, this area may cause your home to overheat, especially on spring and fall days when the weather can be warm but the sun is still low on the horizon. Make sure the architect or designer takes this into account when determining the size of solar-facing windows.

More south-facing glass can be used in a house with a lot of mass. Mass is provided by the building materials used inside the house -- brick has more mass than drywall, for example. Because mass stores solar energy, larger windows can be used without overheating the area. This heat is released at night to offset the windows' higher heat loss. As an example, you

could double the optimum area of south-facing glass if you quadrupled the mass, but this would be expensive (see heat storage, page 7).

The more energy efficient the home, the less heat is required. As less heat is required, solar glazing can be reduced which decreases costs.

By contrast, you can install more south-facing glass if you use windows with more glazings. In an energy efficient Alberta home of standard mass the optimum area of triple-pane solar glass ranges between 12 and 15 per cent of the floor area. The percentage would be lower for double-pane windows. In a super energy efficient home with high levels of insulation, the optimum area for both double and triple is much lower. Remember that the heating bill will always be lower with triple-pane windows because they have superior net heat gains.

Going above or below a range of optimum area means spending more to heat the house. With less than optimal glazing, you are not taking full advantage of the sun; more than optimal glazing means higher night-time heat loss (and more daytime overheating). Variation of heating costs within the range of optimum area is small. At the low end of the range, there will be less overheating and less spent on building materials. Area for area, walls cost less than windows.

Shading solar-facing windows. The path of the sun across the sky from season to season affects the way you design for the sun and for shade. Shading devices should block the summer sun but not the winter sun. Fixed overhangs provide seasonal shade because sun angles vary from summer to winter. On December 21, the day the sun's path is lowest in the sky, the sun is between 10 and 20 degrees above the southern horizon at noon for most of Alberta. On June 21, the day the sun's path is highest, it is between 55 and 65 degrees. As Table 2 shows, sun angles decrease and increase symmetrically on either side of these dates; the sun angles are the same on February 21 and October 21, for example.

Table 2
Sun angles above the south horizon at solar noon (in degrees)

	Lethbridge (49 40'N)	Calgary (51 06'N)	Red Deer (52 10'N)	Edmonton (53 30'N)	Ft. McMurray (56 40'N)
Dec 21	17	15	14	13	10
Jan 21	20	18	17	16	13
Feb 21	29	27	26	25	22
Mar 21	41	39	38	37	34
Apr 21	52	50	49	48	45
May 21	60	58	57	56	53
Jun 21	64	62	61	60	57
Jul 21	60	58	57	56	53
Aug 21	52	50	49	48	45
Sep 21	41	39	38	37	34
Oct 21	29	27	26	25	22
Nov 21	20	18	17	16	13

To design on overhang, decide when you want complete sun, complete shade, and partial shade. If you want little sun in summer, you may choose to completely shade large south-facing windows at noon for two months (from May 21 to July 21). For a sunnier and hotter house, you may want just half shade on June 21. Figure 7 shows how sun angles are used in conjunction with these decisions to determine overhang length.

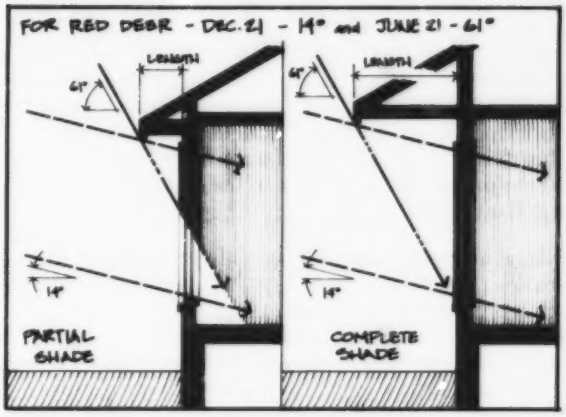

Figure 7 Sun angles and seasonal shade affect the design of fixed overhangs.

The best way to design an overhang is with a sunpath diagram. This is a graph that plots the location of the sun -- both its altitude and its angle off true south -- for any day of the year at any time of day. The Energy Efficiency Branch has sunpath diagrams available on request for eight locations in the province. Call the Energy Matters inquiry line by dialing zero and asking for Zenith 22339 (call 427-5300 in Edmonton).

Remember that decisions about sunlight and shade for one season will affect sunlight and shade in another. If you choose to have complete sun on your south-facing windows until March 21, when the weather can still be cool, it means you will have complete sun starting September 21, when the weather can still be warm. Fixed overhangs are not adjustable for a cool spring and a warm autumn; the sun's height, not the outside temperature, determines the amount of light and shade. For this reason, some designers prefer movable shades such as awnings and curtains, or shade from deciduous trees and vines with leaves that block the sun during the summer and fall. These options have their own complications: someone has to operate awnings, and even leafless trees can block up to 50 per cent of the winter sun.

Slope for solar-facing windows. Sun angles also affect the best slope for solar-facing windows. During the heating season in Alberta, when the sun is low, a window tilted 10 to 20 degrees off vertical will let in a little more light than a vertical window. This is because the sloped window is perpendicular to the sun's rays and reflects slightly less light. Sloped windows are more difficult to install and seal well, and are more exposed to rain and dirt. Tempered glass, which is more expensive, must be used if a window is tilted more than 15 degrees off vertical.

Heat Distribution

Good air circulation is crucial to distributing heat in a passive solar home. Air of different temperatures tend to stratify. Warm air collects in higher spaces near the ceiling or upstairs (vertical stratification) and toward the solar side of the house (horizontal stratification). Circulating the warm air to mix with cooler air below and behind will make best use of the heat and improve comfort. Encourage air circulation in the layout and the design of the heating and ventilating systems.

Improving Natural Convection

If you are building a new home or extensively renovating an old one, consider an open concept floor plan. Open plans allow air to circulate more freely than those divided into many separate rooms. Unobstructed, air will circulate through a passively heated home by natural convection. You can also circulate air with the help of fans.

In summer, encourage good air circulation and ventilation by taking advantage of prevailing winds. Have windows that open into the wind (on the windward side of your house) and more that open away from the wind (on the leeward side). Wind creates negative pressure on the leeward side, drawing air out and allowing air from the windward side to move in. Casement windows (that open and close like doors) are a good option. They can scoop in breezes on the windward side and they seal better than other kinds of operable windows. Planning operable windows in both the upper and lower floors also has an advantage for summer cooling; at night, warm air can escape through upper-storey windows and draw cool air through lower windows.

Fan-Forced Heat Distribution

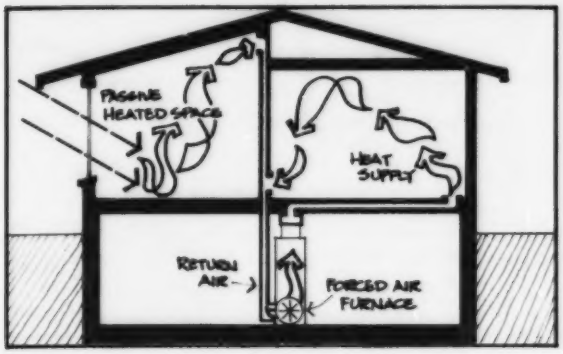

Figure 8 Forced-air heating systems can encourage air circulation.

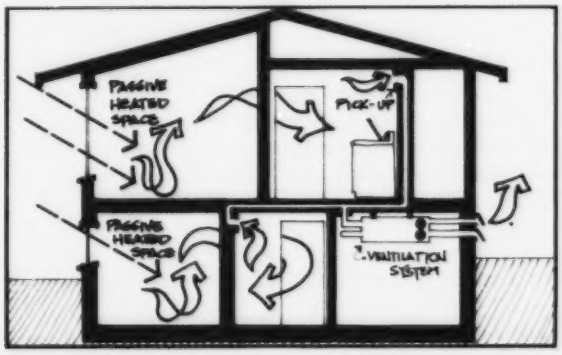

Figure 9 Radiant systems require a separate ventilation system.

Figures 8 and 9 show how to design the heating and ventilating systems to improve air circulation. With a forced-air heating system, put the return air ducts high in a solar-heated space to skim warm air off the ceiling and reduce stratification. With radiant heating, the centralized ventilation system helps circulate air. (We assume a passive solar home is energy efficient and has centralized ventilation to maintain good indoor air quality). Put the exhaust intake grills of the ventilation system far enough away from solar-heated spaces to pull warm air to other parts of the home. Ceiling fans in rooms with high ceilings and fans between rooms also help reduce vertical and horizontal stratification.

When choosing a heating system for a new home, remember that the fans on forced-air systems are much more powerful than ventilation fans or room fans; their continuous low-speed circulation rate is typically 250 to 300 litres per second (500 to 600 cubic feet per minute) compared to about 50 litres per second (100 cubic feet per minute) for a ventilation or room fan. This makes passive solar design and forced-air heating a good combination.

Heat Storage

Storing heat becomes important when you have a lot of south-facing glass but do not want large day-to-night temperature swings. Unless properly designed, an overglazed space will severely overheat during the day and cool down too much at night. Big temperature swings can be uncomfortable for people living in a passive solar house and fatal to greenhouse plants. If a solar-heated space is not a permanent home for either people or plants -- such as a self-contained recreational sunspace -- large temperature swings may be acceptable.

A home with too much glass overheats because it receives more solar energy than it can store. This problem can be corrected simply by exhausting the heat from the house, but it means the heat can not be used later when the house cools down. The other solution is to increase the thermal storage capacity by adding mass. Concrete, brick, stone, ceramic tile, water and extra drywall are commonly used as thermal mass. They reduce temperature swings because they absorb a large amount of heat when surroundings are hot and release it when surroundings cool. Excess daytime heat is thus available at night.

Increasing the area of south-facing windows and adding a lot of mass results in a lower utility bill, but the benefit is small compared to the expense. You will spend more on windows and building materials to trim a heating bill that is already small. Boosting glass area and mass does not have a good payback, but it may make sense if you want more south-facing windows for other reasons such as daylight or a view.

Properties of Thermal Mass

Efficient thermal mass can absorb heat quickly and store a lot of it. Stated more technically, efficient thermal mass should have high thermal conductivity and high specific heat capacity.

A substance with high thermal conductivity transports heat away from its surface quickly. This means it can absorb incoming energy rather than overheating at the surface. The same property allows it to radiate heat quickly when the temperature drops. The higher the specific heat capacity of a material, the more heat it can hold. This means you need less of this material to control temperature swings in a passive solar space. Water holds a lot more heat per kilogram than almost any other common material, but is more difficult to use in a living space than solid mass.

Color and finishing materials affect the performance of thermal mass. Dark-coloured, flat-finished mass absorbs sunlight better than glossy light-coloured mass. Tile and paint are better than carpet or wood because they do not insulate the mass.

Location of Thermal Mass

The best place to put thermal mass is in a space directly heated by the sun. Mass can be put outside the space as long as there is some method of moving solar-heated air to it -- usually an air duct with fans. Without a thermal link, heavy materials outside the passive solar space will have little effect on a home's performance. In a house where the basement is not direct gain space, for example, there is little advantage in choosing a concrete basement over a wood basement.

In a direct gain space, thermal mass works best if it is distributed evenly. At our latitudes, a vertical mass is better than a horizontal one -- a heavy wall is better than a heavy floor -- because the sun is too low during the heating season to have good access to a floor (unless the windows extend close to the floor). If the mass is over a large area -- for example, if extra drywall is used on the ceiling and walls -- it is best to diffuse sunlight over as large an area as possible. Diffuse light by bouncing it off light-coloured surfaces where it enters a room. As much as possible, light-weight objects such as furniture and wood-framed walls should be kept a light colour to help diffuse light and keep these objects from overheating during the day. Light-coloured furniture fabrics will also fade less.

To avoid thermal mass in a direct gain space, use remote storage or mass that is separate from the space. Figure 10 illustrates the difference between direct gain mass and remote storage. To be a passive solar design, the thermal link between remote storage and a solar-heated space should be part of an existing air distribution system. For example, a remote storage mass could be a bin of rocks in the basement (or a room full of containers of water) connected to a return air duct on a forced-air heating system. Air from the solar-heated space would travel through this bin and leave or pick up heat on its way. Remote storage should be insulated from the rest of the house because this allows greater control over the release of heat from the mass.

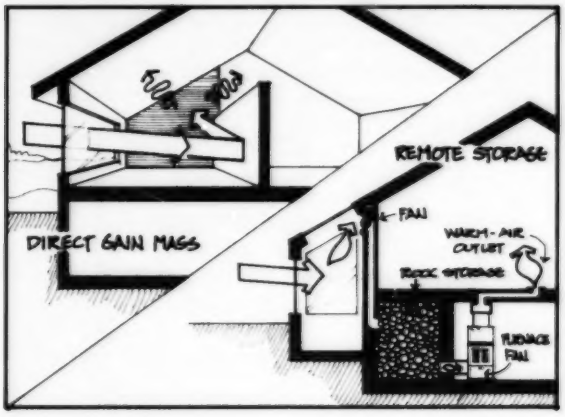

Figure 10 Options for storing heat from passive solar gain

Two Examples of Passive Solar Design

This section shows how the principles for passive solar design in Alberta apply to two examples: a new home and a sunspace added to an existing home both at about 53 degrees north latitude. The examples illustrate problem-solving in the design process and the consequences of following or ignoring the principles.

Designing a New Home for Passive Solar

If you plan to build a new home, you usually have preferences about size, location, general appearance and other features. For example, consider a house for a family of four in a new subdivision. They want the house to look conventional and to operate with few demands on time and attention. In the area they selected, there is a good view of a ravine to the southwest. The family enjoys a lot of sunlight and is interested in making good use of passive solar heating in their new home.

To make best use of passive solar heating, the house will have to be energy efficient. It will be well-sealed with centralized ventilation and well-insulated with an RSI 7 (R 40) ceiling, RSI 5.25 (R 30) walls, and an RSI 3.5 (R 20) basement.

The next step is to choose a house plan and then decide on heating system, orientation, siting and window design (and thermal storage if necessary).

House plan

Figure 11, 12, and 13 show a typical house plan. It looks conventional from the outside -- the amount of glass is not overwhelming -- and allows lots of natural light. The design suits an urban lot because it is narrow and provides access to the garage from the street, useful as many subdivisions do not have alleys. Its passive solar features include:

- **a solar side.** Windows are concentrated on one side to allow good access to the sun. Locating few windows facing other directions helps control heat loss. The solar-facing window area is about 12 per cent of the floor area, within the optimal range for a standard mass house with triple glazing.
- **buffer zones.** On the non-solar side, the house is protected from winter winds by a garage. Spaces not used for living -- such as the bathrooms -- also act as buffers.
- **an open floor plan.** The cathedral ceiling over the living room helps air to circulate between floors. Except for the bathrooms and bedrooms where privacy is important, there are no doors and few walls between rooms and this allows free air movement.

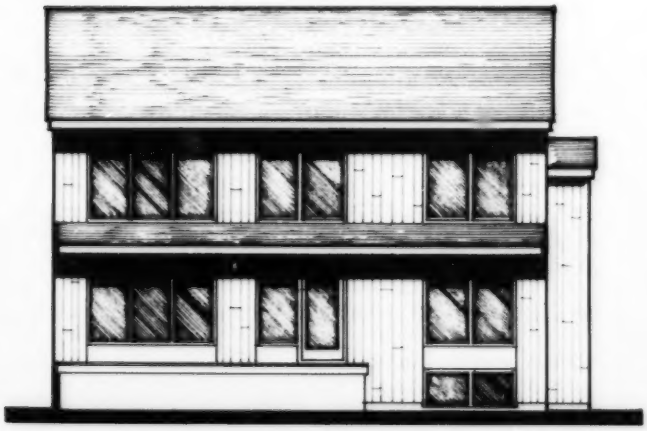

Figure 11 Southwest elevation

Figure 12 Main floor plan

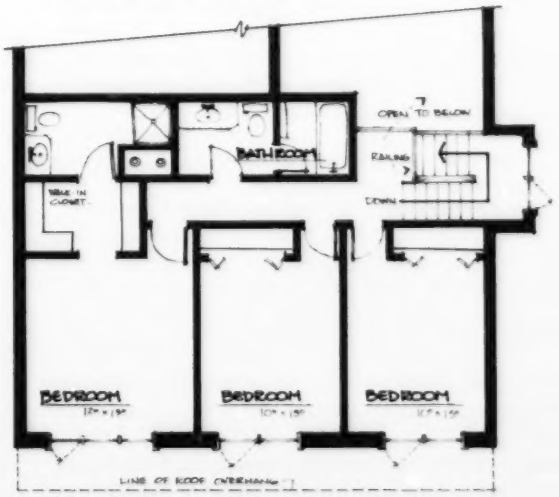

Figure 13 Second floor plan

Heating system

A heating system is usually chosen early in the design process so that placement of ducts, pipes or space heaters can be decided. We have chosen a forced-air natural gas furnace with two-speed fan for this home because it circulates air well. If this house had radiant heating, we would want fans to help circulate air, particularly in the cathedral ceiling.

The return air ducts of the heating system are installed high in rooms to skim solar-heated air off the ceiling where it will collect.

Orientation

The best orientation for the solar side of the house would be south, but we are going to face the solar side southwest to take advantage of the good view. Because the solar side is the back of the house, we have chosen a lot that faces the street in a northeast direction. (See Figure 3. The lot labelled "A" is our choice). If you want to face your home in a particular direction in a subdivision, it is best to buy a lot oriented the correct way. With setback requirements and sidelot restrictions, it is easier to place a house square on a lot than to skew it.

If the solar side of this house were facing south, it would need about 86 gigajoules (GJ) of natural gas to heat each year. This heating requirement does not increase when we turn the house southwest, although we might expect it to. This is because the window over the stairwell, which faces east when the solar side faces south, becomes a southeast window when we turn the house, and its solar contribution goes up. If we faced the solar side due west, the house would need 97 GJ per year of energy, an increase of 13 per cent.

With its solar side facing southwest, our house will be more prone to overheating. It will require particular attention to window shading and possibly more ventilation in the late spring and early fall when temperatures are warm but sun angles for the southwest sun are low.

Siting

The house should be placed on the lot to prevent shading of its solar side by the neighbouring house to the east. By pointing the solar side 45 degrees west of south, some of the prime morning hours are already lost during part of the heating season. Shading on the east would interrupt them more.

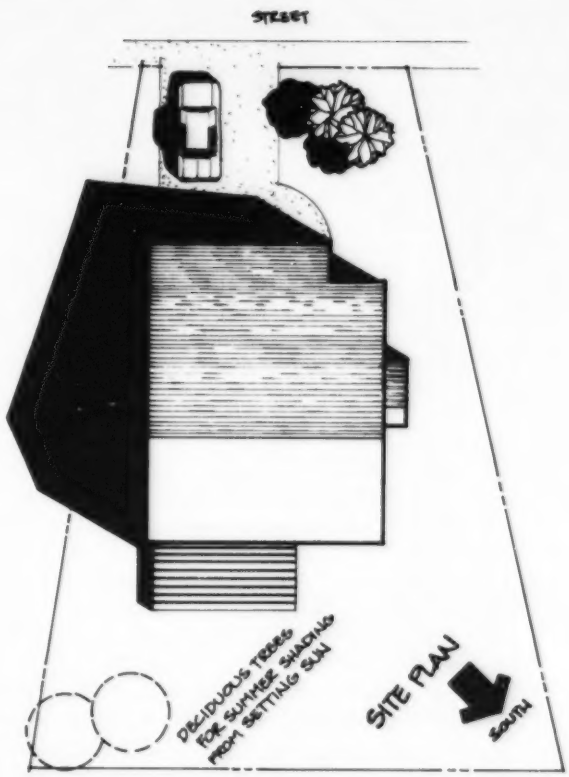

Figure 14 Site plan

The lot can be landscaped to enhance the performance of the house. Deciduous trees on the west corner of the lot will help shade the windows from the setting sun in the summer, while allowing the winter sun to penetrate. The garage acts as a buffer protecting the house from the northwest winter winds. An extra windbreak of conifer trees at the northwest corner could cause snowdrifts across the driveway (Figure 14).

Window design

All windows in the house are triple-glazed to control condensation and heat loss. The heating bill for a home with triple glazing is lower than for a home with double glazing. The house can also have a larger area of triple-pane glass than double-pane glass without a penalty in heat losses. This allows the family more sunlight and a better view of the ravine.

Since the basement is not a direct-gain space, only the main and upper floors are counted when calculating solar-facing window area. These floors have a total area of 195 square metres (2100 square feet). The southwest windows are 23.4 square metres (252 square feet) for a glass-to-floor-area ratio of 12 per cent. The house is on the low end of the optimum range of

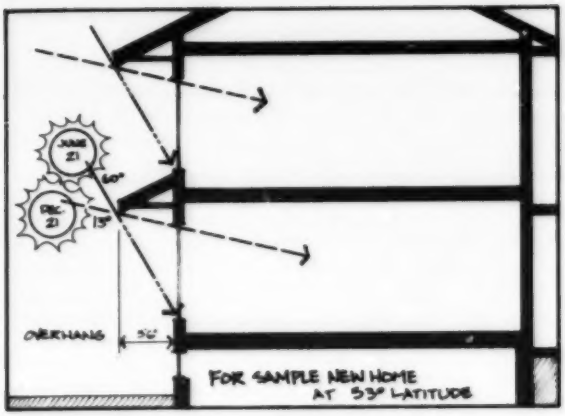

Figure 15 Determining the length of the overhangs

solar-facing window area for its mass and energy efficiency. This is one precaution we have taken to control overheating. As mentioned, the house is already more susceptible to overheating because it faces southwest. Staying within the optimal range also saves the family money: they do not have to spend a lot on extra glass or thermal storage.

The southwest windows are shaded with a fixed overhang. Using the principles described earlier in Figure 7, Figure 15 shows how the length was determined to give complete shade at noon on June 21. A fixed overhang does not give ideal shading for our house because it faces southwest; the sun can still beat directly in the windows when it is in the southwest quadrant and low on the horizon. The overhang would have to be impractically long to shade the windows from the southwest sun. Movable window shading, such as shutters, would be a better solution but the family wants a house that requires little supervision. The deciduous trees on the west corner of the lot are a crucial element in shading the solar-facing windows.

We have chosen operable windows to take advantage of prevailing summer winds from the west. This is another measure that will help relieve overheating. The southeast window over the stairwell opens to help draw air out. On the southwest side, there are operable casement windows on both floors to let breezes in and to encourage air movement between floors. The windows are hinged on their southeast side so that they open to scoop breezes into the house.

Our house does not have insulated shutters because of the added demands it makes on the homeowner's time and attention. Insulated shutters, however, would make a substantial difference to the performance of the house. On our triple-pane windows, RSI 0.8 (R 5) shutters would reduce the annual use of natural gas by about 16 GJ or almost 13 per cent.

Review

This family wanted a conventional house that took advantage of passive solar heating. We started with an energy efficient house and incorporated features such as: large windows on the southwest to give access to the sun and the view; an open floor plan and a forced-air heating system to encourage air circulation; and fixed overhangs and deciduous trees to reduce overheating. Our house is an example of balanced design. It meets many priorities including attention to passive solar features, esthetics, comfort and lifestyle.

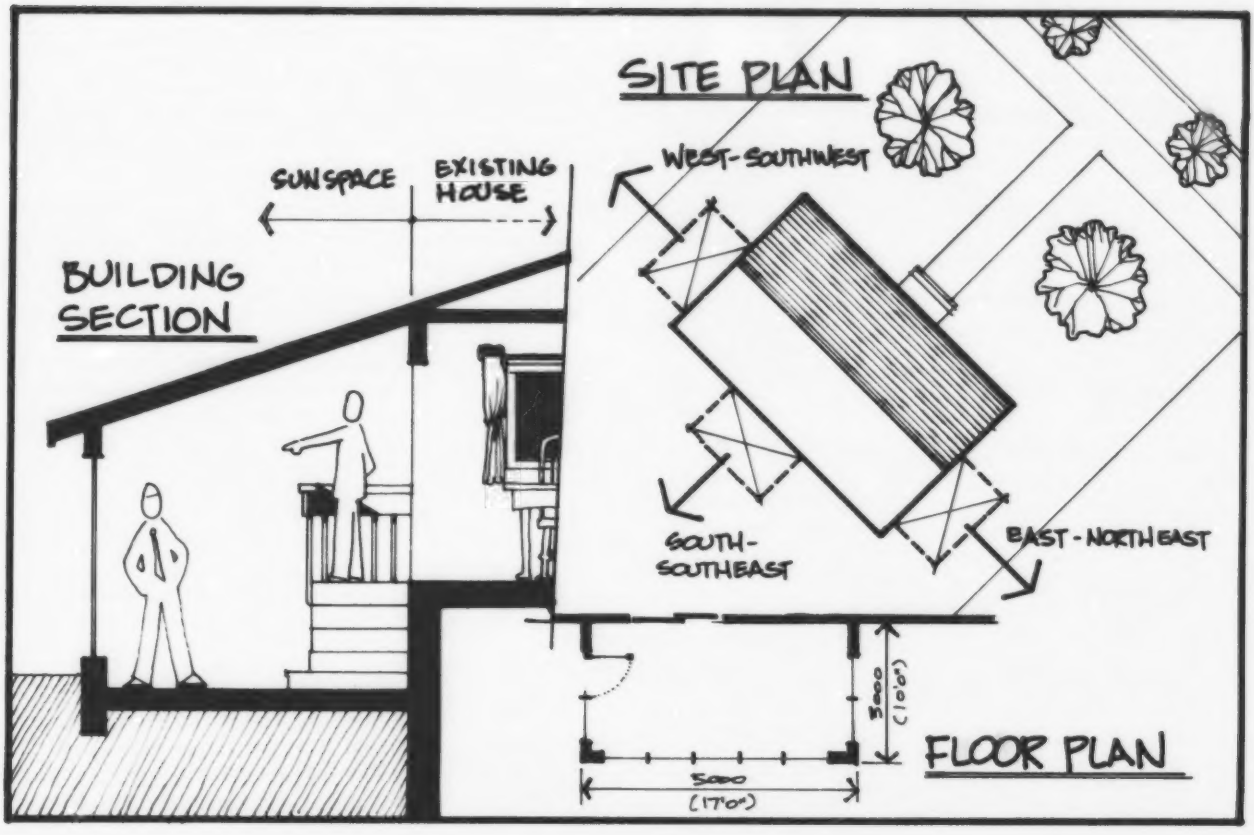

Figure 16 Example sunspace

Designing a Sunspace

Before designing a sunspace, you have to know how it will be used. Will you garden in it? Heat your home with it? Use it for recreation? In this example, we assume that owners of an existing house want to add a sunspace for year-round use as a sitting area. They would like whatever heat they can from it, but are not concerned about making it an important heat source for their home. They want to keep house plants in the space. Their house faces south-southeast and has a forced-air gas furnace.

Floor plan

Figure 16 shows a simple design. The sunspace is about three metres by five metres (10 feet by 17 feet) -- big enough to seat four or five people comfortably. The floor is at ground level, below the main floor of the house, to give it added head room.

The sunspace shares one of its walls with the house and a patio door connects them. The door allows the sunspace to be closed off from the house. The long exterior wall has 9.75 square metres of glass (105 square feet). One of the short walls has window area totalling about four square metres (42 square feet); the other has a patio door to the outside with 3.8 square metres of glass (41 square feet). Each window area by itself far exceeds the optimum glazing levels for the space, but creates the bright environment the owners want.

The ceiling is insulated to RSI 7 (R 40) and the walls to RSI 5.25 (R 30).

Orientation

As Figure 16 illustrates, the sunspace can face one of three directions and still get the winter sun: south-southeast, west-southwest or east-northeast. The difference for solar gain is negligible. Solar contributes about 17 per cent of the heat required in all cases. This is because even the smallest of the three window areas, at 24 per cent of the floor area, can overheat the space. We chose the south-southeast orientation because it gives the space good sunlight all day and orients most windows south where they can be more effectively shaded with a fixed overhang.

Window design

All windows are triple-pane to control heat loss and condensation. Substituting double-pane windows for triple-pane would more than double the amount of natural gas needed to heat the space -- from 11 GJ to 23 GJ per year, assuming an average temperature of 21 degrees celsius (70 degrees fahrenheit) and a day-to-night temperature swing of 5.5 degrees celsius (10 degrees fahrenheit).

The south-southeast windows are shaded with a 1.2 metre (four foot) overhang. This length is considered a maximum by designers. Anything longer cuts off too much view and looks awkward. The overhang will not prevent the space from overheating, but it will help.

Putting in operable windows will help remove overheated air in summer (in winter, the owners will use this heat in their house). Casement windows are used because they seal well and scoop breezes better. Assuming prevailing summer winds are from the west, the best ventilation will occur with an operable window on the east-northeast side (the leeward side) and the west-southwest side (the windward side). On the south-southwest side, windows should be hinged on their east side to catch the wind.

Thermal mass

As the space has so much glass, the question of whether to add thermal mass becomes an issue. We would have to add a lot of thermal mass to this space to reduce temperature swings. We could add it cheaply in the form of water-filled drums, which take up a lot of space and are unattractive. Other types of mass -- brick, gravel pads under the floor -- are expensive, especially as large temperature swings are acceptable because the space can be completely sealed off from the house by closing the connecting door. We have decided not to add thermal mass and will control temperature swings with ventilation and heating systems.

Heating and ventilating systems

The objective of our heating and ventilating design is to isolate the sunspace from the house when it cannot supply useful heat, but to heat the space with the main heating system when it is occupied. In our design, the space is connected to the main heating system by thermostatically controlled return and supply air ducts. The return duct is located near the ceiling. When the sunspace overheats during the winter, the ducts automatically open and the heating system fan circulates the hot air through the house. Note that this requires continuous circulation from the fan. If the furnace does not have a two-speed fan, the owners will have to install one. A wall switch will also open the heat supply and return air ducts to ensure a comfortable temperature is maintained when the space is occupied. A thermostatically controlled 1500 watt electric space heater, kept at a low setting, will keep the space from freezing during winter nights. When the sunspace overheats in summer, it is ventilated directly to the outside by a thermostatically controlled fan (Figure 17).

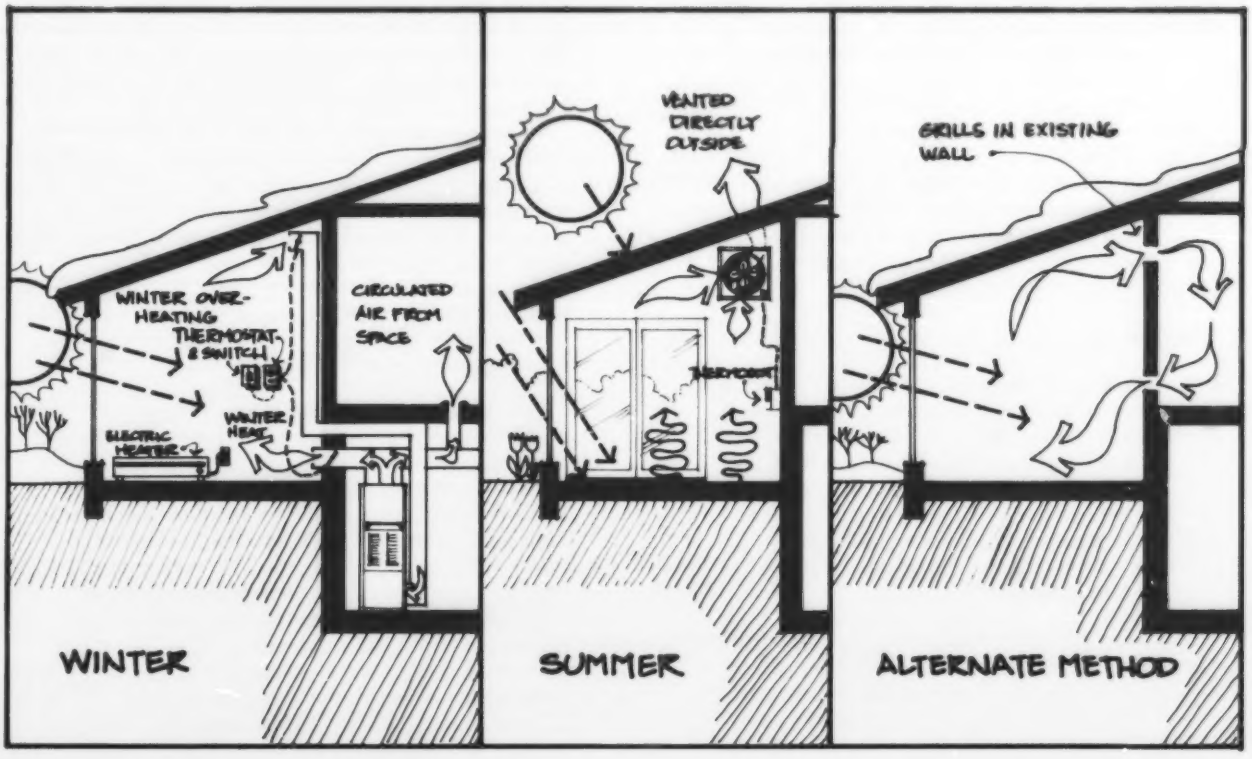

Figure 17 Possible heating and ventilating system design for the sunspace

Review

Heat could also be transferred to the house through vents in the connecting wall that would allow natural convection to circulate air. This would be a more difficult renovation because it would require more holes in the wall. It would also be a less effective and controllable way of ventilating the sunspace when it overheats.

This sunspace has been designed primarily as a recreational area and to take advantage of solar energy. Its key features are: an orientation that gives it light all day; triple-glazed windows that keep heat losses as low as possible; and a heating and ventilating system that provides heat to the home when possible and takes heat only when necessary. The design makes the sunspace a bright, affordable addition to the home and with only a small increase in heating cost.

Summary

The principles described here apply to direct gain passive solar heating in Alberta. The rules should bend to accommodate your needs and tastes. Each time you alter a rule, however, you alter the balance of elements that make passive solar work. A correct balance is crucial to comfortable, usable passive solar heating. Designing balance into your house requires skill and experience. Many architects and designers use computer modelling to analyze the detailed dynamics of passive solar heating.

Passive solar features can be a real benefit to your home. They are simple and affordable, they reduce heating costs, and they help to make your home a bright, comfortable and pleasant place to live.

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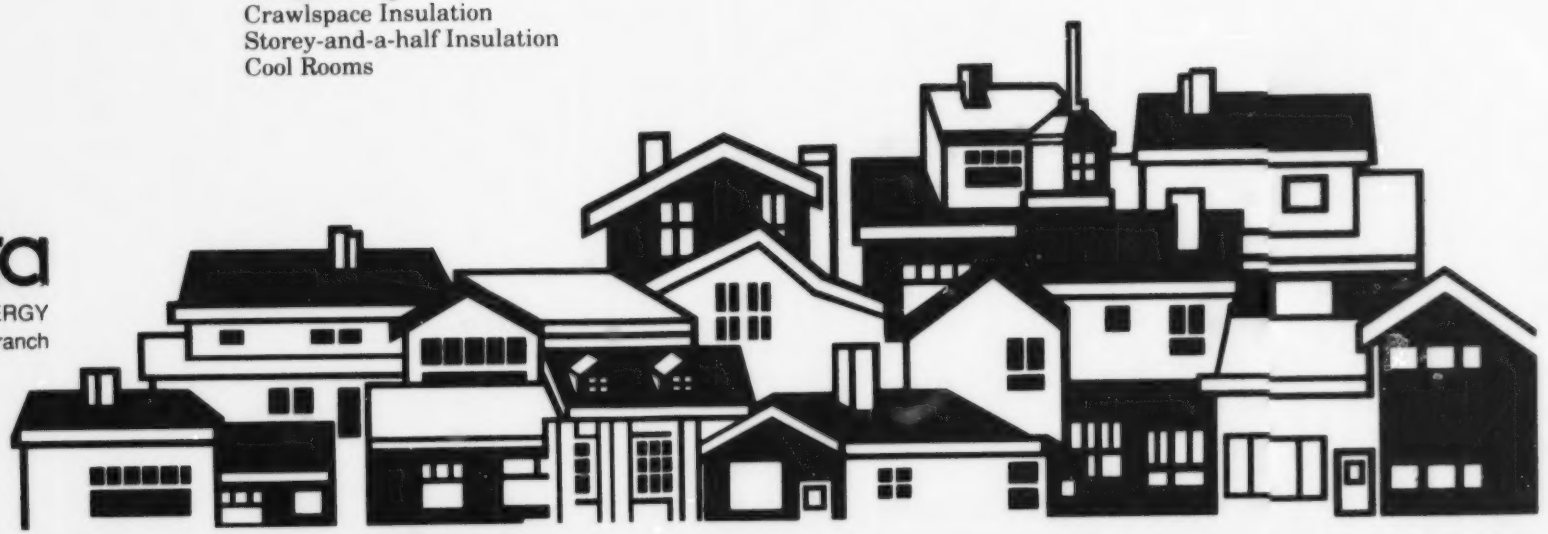

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